Report Prepared for the Research Division
Royal Commission on National Passenger Transportation

Technological Innovation in Transportation R&D Funding Policy and Approach

M. Brenckmann
October 1991

RR-11

Opinions expressed are those of the author and not necessarily those of the Royal Commission on National Passenger Transportation.

Report Prepared for the Research Division
Royal Commission on National Passenger Transportation

Technological Innovation in Transportation
R&D Funding Policy and Approach

M. Brenckmann
October 1991

RR-11

Cat. No. Z1-1989/1-41-11E

ISBN 0-662-19884-0

TECHNOLOGICAL INNOVATION IN TRANSPORTATION

R&D FUNDING POLICY AND APPROACH

prepared for the
Royal Commission on National Passenger Transportation

by
M. Brenckmann
October 1991

Technological Innovation in Transportation
R&D Funding Policy and Approach

Introduction

A premise for this paper, is that the Commission may need to consider recommendations regarding new or significantly updated passenger transportation systems in Canada. In such case, questions will arise about technological innovation and corresponding efforts in R&D required to achieve these changes in the Canadian context.

Public perceptions and expectations in the field of transportation are that improvements, innovation and progress are desirable, possible and indeed imminent. Even a casual review of media presentations on innovation generally will reveal numerous and prominent examples of "new and better" transportation developments, proposals or concepts.

The truth is that innovation in the field of transportation is one of the most difficult, costly and time consuming forms of technological endeavours. The reasons for this are many, ranging from the sheer size of the existing transportation systems to be affected, to the intrusive degree of public and governmental involvement demanded by law, by politics or by other imperatives such as economics, safety or environmental considerations. The usual avenues for change in transportation are evolutionary, with attendant limitations as to results obtained. The transportation industry and its equipment suppliers have thus over the years become markedly conservative, risk avoiding and cautious vis-a-vis radical change. They are particularly averse to external pressures for change when economics are uncertain or negatively affected.

It should be made clear at the outset that technology innovation and attendant R&D in transportation belong to the domain of "development" rather than "research" and, furthermore, that these activities cannot be considered as "discretionary" as some would have it. Technology in its application to transportation is essentially based on thorough investigations of numerous technical and operational questions, problems, unknown phenomena, and particularly, crucial safety issues. As each application is unique in many respects, new technology cannot be put into practice (that is in revenue service) until all these questions have been answered to the full satisfaction of all those concerned, including the public. To arrive at these answers, significant R&D resources have to be made available, without guarantees of commercial returns, in other words as high risk investment. These R&D expenditures, however, are a *sine qua non* condition for innovation to reach the pay-off stage.

There are also special difficulties affecting R&D programs supporting transportation initiatives. While such activities follow the usual steps in an innovative cycle, such as:

basic discovery,
proof of concept,
prototype design and testing,
in-service testing for performance,
safety,
economics,
governmental certification, and eventually
system deployment within an operating territory

The latter phases of this cycle are beyond the capability or the purview of the originators of the technology (see also figure 5). In other words, successful completion of the innovation cycle depends as much on technological successes at each stage as on the availability of steeply increasing resources and the commitment of a diverse set of stakeholders that are drawn in as the project progresses. The risk capital required to sustain this effort is for the most part not available under commercial terms in Canada, and government intervention becomes essential.

Even when technology has been developed abroad and is being imported, its adaptation to a Canadian application still requires R&D to be conducted in Canada. This is because a substantial portion of the innovation cycle has to be performed on site, starting, for instance, with in-service tests, with the heaviest cost and risk burdens outstanding.

Then there are also the questions about a domestic technology base (usually a branch of a multinational industry) which has to be *brought up to speed* through *hands-on* experience with the R&D, in order to be able to monitor and further develop the technology in response to emerging circumstances in Canada. This represents additional demands on R&D resources, often omitted in initial proposals.

These cautionary introductory remarks should serve as a warning that transportation R&D funding and R&D approach will have to depart from classical venture capital and free enterprise models. Mixed economy practices and broadly distributed decision making are called for. This will affect the mix of funding sources, according to the costs and benefits to the supply industries and operating organizations, and it will require taking into account public (social) costs and benefits.

R&D Funding Levels

For the purposes of the review of statistics carried out in this paper, the field of transportation and related technology is treated as a whole, not differentiated as to freight or passenger services. This is necessitated partly by the format of relevant data, but also because many of the technology considerations are of interest for both types of services.

Furthermore, the point of view is taken in this paper that the principal motivation of the R&D undertaken is to improve the Canadian transportation system, including all its national and international impacts, leaving industrial development and exports of the transportation equipment manufacturers as a secondary goal.

It became evident during the preliminary search for data for this paper, that specialized data on R&D funding applicable to transportation have not been forthcoming in recent years, apparently due to general budgetary restraint. Most of the data quoted date from the mid 80's and are therefore offered as orders of magnitude of the subject activities. Some of the comparisons are made between Canadian and U.S. data, taking advantage or confirming known similarities and compatibilities of definition.

The global situation regarding Canada's performance in R&D relative to other developed countries has been well documented and this forms part of several public or governmental declarations on the subject (see references 1 to 3 and Figure 1). The interpretation given to these statistics (expressed as gross domestic expenditures on R&D as a percentage of gross domestic product or GERD/GDP) is that Canada would have to double its total R&D effort to catch up on its principal trade partners or competitors. This global assessment does not convey, however, the true message as far as a specific economic domain, such as transportation, is concerned.

In order to come closer to reality, it is useful to establish a sense for the orders of magnitude involved in providing transportation on a national scale. This is indicated in Figure 2, as a side by side comparison between Canada and the U.S.

While the U.S. statistics on comprehensive transportation expenditures have been documented for many years (see reference 4), similar statistics for Canada were not available from a single source. Estimates given here relied principally on reference 5 and on derived expenditures based on such data as automobile fleet size or marine shipment tonnage. These estimates have, however, been recently corroborated by independent work (reference 6 and 7).

The main message to retain here is that, in 1985, transportation in Canada represented some $ 80 billions worth of activities, or 17% of GDP, absorbing 9% of the total labour, costing directly 13% of personal income and overshadowing as an economic sector the combined revenues of farming, forestry, fishery, and mining.

Road transportation represents by far the largest part of the total and this holds for road passenger transportation in relation to total passenger transportation. Turning now to the R&D effort, it is pointed out that the technologies involved are extremely diverse, from advanced energy conversion techniques to complex systems management, communication and control networks, for instance. Technology stems from a variety of equipment manufacturers and research facilities, domestic and foreign, or it is applied and modified to suit Canadian requirements by private operators, large and small, or by government organizations. The R&D expenditures incurred by these groups in Canada can be evaluated as a percentage of the total transportation costs.

This is done, quoting again both Canadian and U.S. figures, in Figure 3. Here, more pronounced differences begin to emerge. Firstly, both in Canada and the U.S., the federal R&D expenditures on transportation are a small percentage of the total transportation cost (0.1% and 0.15% respectively). In Canada, provincial governments also participate in R&D funding, but at a much lower total level ($15 million/year or 0.02% of transportation costs).

Secondly, in Canada, the total transportation R&D effort as a percentage of the total transportation cost is considerably lower than the global GERD/GDP usually quoted (0.56% rather than 1.4%). This means that transportation in Canada, contrary to public perception, ranks lower than average in innovation or technology intensiveness among other industrial sectors. In the U.S., these ratios are closer to each other (1.4% rather than 2.8%), although transportation R&D is also lower than average. This finding is a reflection of the heavy dependence in Canada on imported equipment or systems used in transportation, usually of well proven and somewhat dated type or generation.

Some further trends become evident when the transportation statistics are separated into aeronautical and non-aeronautical (road, rail, marine) sub-categories (see Figure 4). While air transportation continues to be supported by a relatively vigourous technology effort and an innovative industry, domestically and internationally, other forms of transport are not in this position. The meagre R&D activities in Canada for road, rail and marine transportation (0.24% of road, rail and marine costs) are shown to be out of

proportion with the impact these modes have on the national economy and other national aspirations.

In terms of international comparisons, it is clear that transportation R&D in Canada is only one twelfth to one fifth of what a national target figure might be (say 3% of transportation cost) and, as such, substantially below other industrialized countries. Such a shortfall cannot be corrected by marginal adjustments to the R&D funding policies in the private or public sectors, it must be addressed as a radical departure from current practices that date from when Canada's economy was centred on resource exploitation.

Summarizing these findings, keeping in mind that orders of magnitude rather than subtle statistical differences have been discussed, one can state that Canada has not generally been in the forefront of technological innovation in transportation in recent times, as evidenced by the level of effort in relevant R&D.

When considering future alternatives, opportunities or challenges in inter-city passenger transportation, it is important to realize that a new technology initiative, even if imported, would require a very substantial change in attitudes and behaviour on the part of governments, industry and the R&D community in Canada.

A characterization of transportation R&D programs in Canada

The private sector carries an important proportion (74% in $ terms) of the total transportation R&D programs in Canada. Unfortunately, the very nature of this product oriented work, being proprietary and confidential, usually precludes access to detailed information conducive to analysis. It can be deduced, nevertheless, from past experience and from the type of industries concerned (aeronautical, automotive, electronics, railway equipment), that the objectives of the R&D performed are not generally set to serve national transportation priorities. They are quite properly set by corporate priorities. While significant technology achievements have resulted from this R&D stream, very few of these have subsequently led to a major implementation of the innovation in the Canadian transportation system. Most of these successes found their mark in the export markets.

The transportation R&D programs directly sponsored by governments are well documented, usually through annual reports such as references 11 to 15, covering 1989/90. These show that some of the complexities of transportation R&D, as practised in Canada, derive from the jurisdictional division of responsibilities between the federal government (principally

concerned with air, rail and marine modes) and the provincial governments (with main interest in the road mode and also directly responsible for university funding). Within the federal programs, further differences show up between the perspective of a line department like Transport Canada, giving priority to operational, safety and regulatory topics, and that of a research organization like the National Research Council of Canada, concentrating on providing national engineering facilities and related technological expertise.

Each of these programs attempts to span a wide range of technologies applicable to various aspects of transportation. For Transport Canada these include marine navigation, icebreaking vessels, Canadian Coast Guard requirements, air navigation and control, airport security, man-machine interfaces, computer and microelectronics applications in the rail and road modes, energy conservation and substitution, innovation in accessible services, techniques to reduce environmental impact and cooperation in joint R&D with the provinces. For the NRC, these include ice tank technology, marine/ice mechanics, Global Position System (GPS) technology evaluation, Artificial Intelligence (AI) applied to control and training systems, explosive detection, rail and road heavy vehicle dynamics, environmental testing, engine and fuels testing, aerodynamic testing and computational fluids dynamics.

These listings are not meant to be exhaustive, rather they convey the diversity of content of these programs, with several hundred active projects running simultaneously. The annual reports also point out the high degree of coordination and consultation which take place with public and private client and peer groups in the program planning stage. It must be concluded that a large proportion of these programs indeed respond to the priorities and essential needs of departments and transportation operating organizations.

The net result, however, taking into account the funding levels available, is that individual technology areas, such as cited in the annual reports, are being addressed with generally less than $500,000/year, or with less than 5 R&D person-years.

Turning now to the transportation R&D programs funded by the provincial governments, these are in aggregate much smaller in $ terms than the federal involvement. Nevertheless, as exemplified by references 13 to 15, there are some noteworthy trends. The largest program is Ontario's, which comprises R&D elements on highway civil engineering and safety, vehicle technology and testing facilities (including energy efficiency and substitution aspects), rail and advanced transportation systems, transportation control

(including vehicle location, communication, control and monitoring) and traffic and decision systems.

Quebec has, over the last few years, considerably enhanced its transportation R&D program, including projects in all modes, involving university researchers and industry participation, in part within a cooperative R&D program under the Canada-Quebec Economic and Regional Development Agreement. In Alberta, a 5 year R&D planning process has firmly established a continuity of effort in road and civil engineering technologies. Finally, all provinces and the federal government, under the aegis of the Transportation Association of Canada, are participating in cooperative R&D, such as the 7 year, $ 5.56 million Canadian Strategic Highway Research Program (CSHRP), undertaken in conjunction with the much larger U.S. SHRP program.

There is, as for federal programs, a great deal of emphasis in the annual reports on the high degree of consultation and coordination in place, giving assurance that duplication is being avoided and that common problems are dealt with cooperatively.

The main impression gained from a review of the transportation R&D programs of the provinces, comprising also more than a hundred active projects, is again the low level of resources assigned to individual technology areas, running generally at less than $ 100,000/year, with many projects below $10,000/year.

The overall characterization that one can draw from the above documentation is that real technological needs pertaining to national or local transportation systems are being addressed through monitoring studies, laboratory investigations, prototyping at the industrial/operational level and sometimes in revenue service when circumstances permit it. This applies in most cases to modest, evolutionary technological advances. The level of support available only very rarely allows these activities to reach the threshold necessary to motivate the private sector to launch a major development, typically requiring R&D efforts in the $ multimillion/year range over the long term.

This is not to say that federal or provincial organizations now engaged in transportation R&D could not play a more decisiv_e role in supporting major technological advances within a new national initiative in transportation. It has to be understood that, for this to happen, appropriate long term dispositions regarding dedicated resources and mandates will have to be put in place.

While there is a strong case for stating that transportation R&D is underfunded and lacks priority in Canada, it would not be sufficient to seek more resources from government or industry to launch a new technology initiative in transportation. Other questions will have to be addressed regarding the interplay of all the participants and stakeholders, the fostering and maintaining of an improved R&D climate, the upholding of continuity of effort through the implementation phase and successive technology generations and defining the proper objectives and incentives. In other words, an approach to innovation and R&D suitable to the circumstances and benefitting from past experience should be taken.

The remainder of this paper deals with these aspects.

An Approach to Innovation and R&D

As pointed out in the introduction, and illustrated in Figure 5, the innovation cycle typically applicable to transportation has some very special characteristics not found elsewhere.

Its most distinct feature is its cycle duration. This ranges, depending on the type of innovation, from 5 to 25 years. This is far beyond a fiscal period, the duration of a government's mandate, or a single industry's planning or financing cycle. That this is no exaggeration may be verified through some current examples:

a) the launch of every new transport aircraft, risking the whole enterprise each time, and occupying at least a decade.

b) the launch of the TGV in France and its prior development since the 1960's (similar experience in Japan).

c) the introduction of composite materials for structural components in high speed vehicles (still in progress after 20 years and not yet fully certifiable in civil aviation).

d) the introduction in service of polar class icebreakers and commercial arctic class tankers in Canada (paced by uncertain commercial developments in the Arctic).

e) the full application of automatic train control systems (ATCS) in mainline rail service in North America (beyond the year 2000).

f) the current attempts and future moves to use non-petroleum fuels for the road modes (possibly by 2020).

This extremely long innovation time scale makes it futile to try to marshal a critical mass of resources in times of financial restraint by consolidating existing R&D funding into a single priority initiative. Other pressures and changing circumstances would soon erode the consolidation and lead to abandonment of the initiative. The only possible course of action is to dedicate R&D funding to a particular major initiative, supplementary to existing funding programs, which are in any event only adequate to sustain a minimum level of competency. In addition, such a major initiative has to be bolstered by overarching dispositions recognizing the needs for sustained R&D efforts, possibly over decades.

A second important feature shown on Figure 5 is the progressively increasing complexity brought about by participants and stakeholders as they are drawn in through successive phases of the innovation cycle. All of these groups must cooperate and strive for compatible goals and this should be laid down in agreements arranged in advance of events, long before pay-offs are in sight. Most failures or delays suffered in transportation developments in Canada have arisen not because of a lack of funds *per se*, but due to poor communications and understanding between those promoting the innovation, those regulating the process, the end user operators and the public sectors and communities affected. In addition, very few projects to date have realistically faced up to these difficulties by ensuring the required coordination and enforcing the necessary long term discipline and respect for obligations undertaken.

In examining how large and ambitious transportation developments are carried out in countries such as Japan, Germany, France or the U.K., as contrasted to what happens in North America, one is struck by significant differences:

a) Most such initiatives were carried out with strong political and governmental backing, within a state run transportation system, utilizing national research facilities and education institutions, with massive industry participation based on a mutual understanding about long term objectives and the need to cooperate, often under the rationale of standing up to potential competition from the U.S.

   An illustration of this approach was recently afforded to Canadian delegates during a visit organized by the Transportation Association of Canada to six European highway

technology institutes in Sweden, Denmark, Belgium, Germany, France and the U.K. (reference 16). These institutes comprise extremely well equipped laboratories, employ cumulatively 2,000 persons (1,000 professionals) and dispose of (mostly government-sourced) budgets totalling $160 million/year. An equivalent effort towards highway technology in Canada (based on population and GDP) would call for an institute with a staff of 250 (125 professionals) and a budget of $32 million/year, which exceeds by far the total resources of the federal and provincial governments devoted to this special aspect of transportation R&D.

b) While equivalent initiatives could take place within the free enterprise system in the U.S., in view of its sheer size, only a few have been undertaken (notably in aeronautics) and these have benefitted from hidden subsidies through military contracts. A similar inconsistency shows up in the extremely vital U.S. highway transportation system powered by giant automotive industries, but made possible by highways constructed with government funding, in parts under a strategic defense rationale. Another intervention by the U.S. federal government in the field of transportation R&D is currently proceeding as the 6 year, US$ 150 million Strategic Highway Research Program (SHRP), aimed at developing better construction, preservation and maintenance techniques to be used over the whole U.S. highway system.

c) In Canada, we have a situation where transportation operating industries are financially strapped and are jealously guarding their ability to shop worldwide for their equipment; where the transportation equipment manufacturing industry is primarily engaged in exports development; where the government levels and departments concerned are striving to reduce their purview and exposure to costs to the strict minimum, regionally or nationally; where the R&D community is all too aware of its precarious influence and financial base. As a result, transportation R&D in Canada has for the most part been an exercise in the art of the possible, seizing on a number of specific opportunities (so-called niches), seeking over the years to satisfy the needs of passenger and freight transport by air, rail, road and water, with correspondingly modest results.

Keeping these limitations in mind, there have been, nevertheless, quite a few important lessons learned about which approaches to transportation development had more success in mitigating the above mentioned

shortcomings. These are listed below in point form, as recommended features for any technological innovative transportation development program in Canada:

1) Strong advocacy at highest level, preferably with a designated champion to carry the torch through unavoidable vacillations in the economy, the industry, public opinion and the government (example: the STOL project, except for its premature termination).

2) The adoption of a rationale, a theme and a financial framework robust enough to stand up for the duration required (5 to 25 years), with reviews and decision points, but safe from budgetary cuts of convenience (example: as far as theme is concerned, the policy to achieve excellence in navigating in ice-covered Arctic waters).

3) The enrolment at an early stage of future participants, beneficiaries, contributors, regulators and others into binding arrangements covering funding, criteria, roles, time scales, public relations and any other relevant activities which would require cooperation, information and decision making (example: the Energy R&D Program, see below)

4) The recognition for public concerns or issues and their incorporation into program plans, from the start and as the program evolves, particularly as these concerns may derive from the objectives of the transportation innovation and its implementation (example: current or future "Green Plan").

An interdepartmental, intergovernmental and international approach that has had reasonably good results to date in Canada has been mentioned above and is briefly described here (see also reference 17). The Energy R&D Program is a Canadian R&D enhancement program, now in its 17th year of operation, currently at the $ 90 million/year federal funding level. The program is led by the federal department of Energy, Mines and Resources but managed by 14 other federal departments, including Transport, with extensive industry consultation and cost sharing participation. The purpose of the program is to accelerate the process of technological change in all energy related or energy dependent sectors of the Canadian economy in response to worldwide events and trends regarding energy availability, prices and social costs, including those due to environmental impacts of energy use. Strong linkages exist between this program and international R&D efforts sanctioned and monitored by the International Energy Agency (IEA) and the Organization for Economic Cooperation and Development (OECD).

This program has been successful in obtaining repeated multiyear resource allocations, thus ensuring continuity of research efforts, mainly due to its comprehensive organizational structure and the resulting cohesive support it enjoys from industry and government, at home and abroad, as well as from the public.

The closing remarks of this paper will condense the preceding thoughts into a set of recommendations and conclusions addressed to the Commission.

Recommendations and Conclusion.

Assuming that the Commission will raise questions concerning technological innovation in the Canadian passenger transportation system, the following recommendations are offered:

1) There are no easy shortcuts for the adoption of new technology to improve a national transportation network. Whether the technology is imported or home grown, associated knowhow and development capabilities need to be built up in Canada, on an existing base preferably, at considerable cost (say several % of capital cost) and over the long run (5 to 25 years).

2) R&D resources required by such an initiative cannot be carved out of existing industry funding sources or government *A-base* budgets, given the very low levels currently available. Such new R&D resource requirements should be viewed as venture capital, preceding the commitments to implement a new system by many years.

3) A most important task which the Commission could initiate would be the definition of a technology innovation "cause" for better passenger transportation in Canada, and also to search for a champion to carry this cause. The public at large would have to be able to recognize the long term merits of such a cause and the future participants in such a venture would have to become staunch supporters as well. A footnote lists a few potential topics, drawn from the predominant road mode, as examples[1] (also see references 18 and 19).

---

[1] Example 1: the future automobile under policies ensuring sustainable development.
Example 2: road transport based on alternative fuels compatible with domestic energy production priorities.
Example 3: international cooperation to reduce environmental impacts of the automobile and including modal shift or multimodal aspects.

4) The Commission could also map out a process through which the consultation, cooperation, coordination and mutual commitments between all the participants or stakeholders of the initiative would take place. This would include federal-provincial-industry linkages as well as international agreements. The resulting body of expertise, decision making powers and sources of influence would then be in a position to justify and obtain the necessary R&D resources.

These recommendations may seem overly cumbersome simply to launch R&D efforts which would be quite modest in comparison to system implementation costs. They are, nevertheless, based on many past experiences and disappointments within the "system" as it exists in Canada. These derived to a large extent from the lack of more permanently established institutions and traditions concerned with industry-government-research dialogue on techno-economics, venture capital formation and industrial/environmental strategies.

It is not the purpose of this paper to pursue this institutional issue further. Suffice it to say that a passenger transportation initiative calling for significant technological innovation can be configured to satisfy existing review and approval mechanisms. In particular, it should be presented as soon as possible before the Council of Science and Technology Ministers and introduced into their Framework for Action.

In conclusion, it is hoped that the Commission, should it have found reasons to recommend technological innovation to improve passenger transportation in Canada, would become the triggering factor in the start of a new era for transportation R&D. After all, it was the preceding Commission on Transport some 30 years ago which changed the general views on transportation in Canada and, after the National Transportation Act of 1967, eventually led to the creation of the former Research Branch of the Canadian Transport Commission, the (renamed) Transport Development Centre of Transport Canada, the (renamed) Transportation Association of Canada and a distinct Transportation Technology Program at the National Research Council. Now may be the time to aim at a more specific target, such as the application of 21st century technology to passenger transportation.

List of References in the Text and Figures:

1- National Science and Technology Framework for Action, Council of Science and Technology Ministers, May 1991

2- Science and Technology Indicators, 1988, Statistics Canada 88-201

3- Canada's Roadway Research Agenda 1991-1993, Transportation Association of Canada, June 1991

4- Transportation in America, Eno Foundation for transportation Inc., 1990

5- Canada Yearbook, 1990, Statistics Canada

6- The importance of transportation in the Canadian economy, P. Zalatan, J.P. Roy, Proceedings of CTRF, 1991

7- The size of the transportation System in Canada, 1980-1988, R. Leore, Working paper RCNPT, 1991

8- Transportation R&D in Canada, Situation Reports 1984/85 and 1985/86, Transport Canada TP 7813E

9- Statistical Abstracts US, 1990, US Bureau of Census

10- Industrial R&D Statistics, 1987, Statistics Canada 88-202

11- TDC Annual Review 1989-1990, Transport Canada TP3230

12- Transportation Technology Program Annual Report 1989/90, National Research Council Canada, NRC 32437

13- Operational Plan 1991, Transportation Technology & Energy Branch, Ministry of Transportation of Ontario

14- Sommaire des activités 1990-1991, La direction de la recherche Ministère des transports, Gouvernement du Québec, RTQ-91-07

15- Five Year Plan 1991-1996, Research and Development Branch, Alberta Transportation and Utilities, ABTR/RD/RR-91/06

16- Visit by the Canadian Delegation to European Road Research Facilities, May 1990, Report to TAC

17- Plan of the Energy R&D Program , Overview , Dec 1990, EMR Office of Energy R&D

18- Transport Policy and the Environment, ECMT Ministerial Session, November 1990

19- Low Consumption, Low Emission Automobile, IEA OECD Proceedings of an Expert Panel, February 1990

GROSS DOMESTIC EXPENDITURES ON R&D

COUNTRY	GROSS DOMESTIC PRODUCT
	%
JAPAN	2.8
UNITED STATES	2.8
SWEDEN	2.7
GERMANY	2.7
FRANCE	2.3
UNITED KINGDOM	2.3
CANADA	1.4

Source: 1988 Statistics Canada 88-201, values for 1985.

FIGURE 1 International Comparison of R&D Funding in Relation to Production.

INDICATORS FOR 1985	CANADA (Can$)	U.S. (US$)
	($ billions)	
GROSS DOMESTIC PRODUCT	480	4,000
TOTAL COST OF TRANSPORTATION	80	755
(% of GDP)	17%	19%
TOTAL COST OF ROAD TRANSPORT	64	600
(% of GDP)	13%	15%
LABOUR IN TRANSPORT	10%	9%
PERSONAL EXPENDITURES ON TRANSPORT	16%	14%
REVENUES OF FARMING, FISHING, FORESTRY AND MINING	50	---

Sources: 1990 Canada Yearbook
1990 Transportation in America (Eno Foundation for Transportation Inc.)

FIGURE 2 Absolute and Relative Economic Importance of Transportation in Canada and the U.S.

ORDER OF MAGNITUDE INDICATOR FOR MID 80's	CANADA (Can$)	UNITED STATES (US$)
TOTAL COST OF TRANSPORTATION (millions)	82,000	755,000
FED. GOVT. TRANSPORT R&D EXPENDITURES (millions)	74	1,100
(% of tot. transp. cost)	0.09%	0.15%
NATIONAL TRANSPORT R&D EXPENDITURES (millions)	450	11,000
(% of tot. transp. cost)	0.6%	1.4%

FIGURE 3 Government and Total National Transport R&D Expenditures in $ or as a % of Total Cost of Transportation

ORDER OF MAGNITUDE INDICATOR FOR MID 80's	CANADA (Can$)	UNITED STATES (US$)
TOTAL COST OF ROAD, RAIL, MARINE TRANSPORT (millions)	76,000	700,000
NATIONAL R&D EXPENDITURES ON ROAD, RAIL, MARINE TRANSPORT		
($ millions)	170	6,000
(% of road, rail, marine cost)	0.22%	0.86%

Sources:
- Transport Canada TP 7813 1984/85, 1985/86, Transportation R&D Situation Report
- Statistical Abstracts US 1990, US Bureau of Census
- Transportation in America 1990, Eno Foundation for Transportation Inc.
- Statistics Canada 88-202, Industrial R&D 1987

FIGURE 4 National R&D Expenditures on Road, Rail and Marine

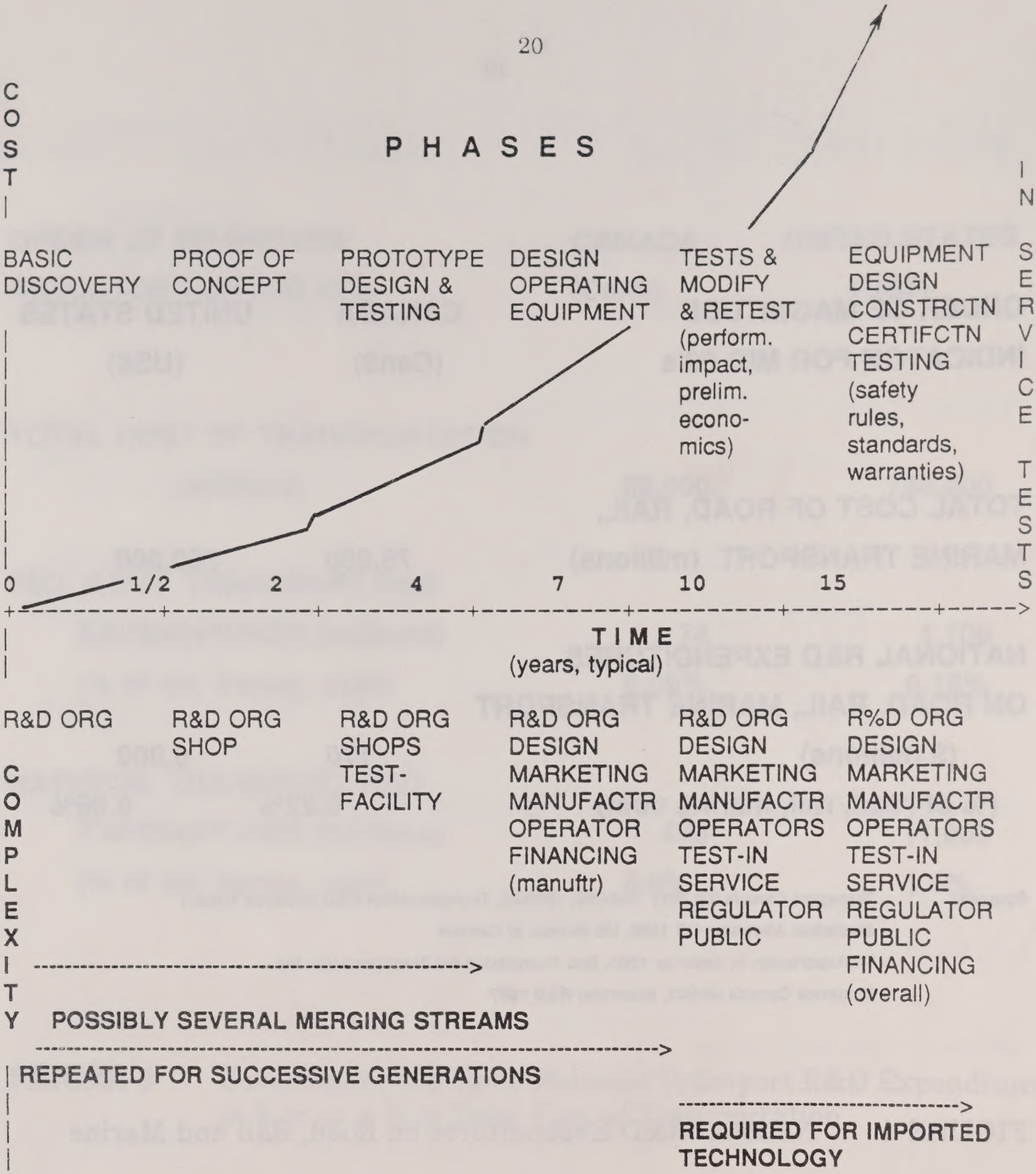

FIGURE 5 Innovation Cycle as Applied to a Transportation Development